SUMMARY OF INFORMATION AND REFERENCES ON THE TOXICITY OF METALS TO AQUATIC ORGANISMS

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Ministry of the Environment
Ontario

The Honourable
George R. McCague,
Minister

K.H. Sharpe,
Deputy Minister

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SUMMARY OF INFORMATION AND REFERENCES

ON THE TOXICITY OF METALS TO AQUATIC ORGANISMS

HAZARDOUS CONTAMINANTS
AND STANDARDS BRANCH
135 ST. CLAIR AVENUE WEST
TORONTO, ONTARIO M4V 1P5

by

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and

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under the auspices of PLUARG

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INTRODUCTION

Knowledge about the lethal and sublethal affects of metals is voluminous. The time spent annually by individuals gleaning information from the hundreds of publications and reports is substantial. This compendium of information has summarized some of the salient features of the more commonly investigated metals, in the hope that it will reduce time spent on literature searches.

The data sheets outline, briefly, some predominant characteristics of each metal. References are given for more detailed study.

Organism	LC_{50}	(Ref. #)	TOXICITY DATA Sublethal	(Ref. #)	Other	(Ref. #)
ALUMINUM						
adult fish Rainbow trout fingerlings	@ 44 ppm no mortality	(111)	@5.2 ppm Al (aqCl) & pH 8.0 feeding activity reduced drastically over 24 hrs.	(112)	dissolved and suspended forms of aqueous Al are toxic to r.b.t.	(112)
shrimp	@44 ppm no mortality	(111)				
oysters	"	(111)				
Speckled trout	@ 8 ppm no mortality	(111)				
Redfish	"	(111)				
Grand killifish	"	(111)				
Gulf killifish	"	(111)				
Sheepshead minnow	"	(111)				
Brook trout	@ 5.2 ppm no mortality	(112)				
eels (young)	36 hrs @2.7 ppm, 100% mortality 50 hrs @ 0.27 ppm no mortality	(113)				
Scenedesmus	@ 1.5 - 2.0 ppm	(108)				
Daphnia	96 hr. @ 1000 ppm no effect	(108)				

Organism	LC_{50}	(Ref. #)	TOXICITY DATA Sublethal	(Ref. #)	Other	(Ref. #)
ANTIMONY						
Daphnia	96 hr = 20 ppm	(38, 39)	found no correlation between tissue concentration and age of S. numaycush	(129)		
Bacteria	48 hr = 33 ppm	(108)				
Scendesmus	96 hr = 3.5 ppm	(108)				
Fathead minnows	96 hr = 9-80 ppm dependent on water hardness	(39, 106)				

Organism	TOXICITY DATA LC_{50}	(Ref. #)	Sublethal	(Ref. #)	Other	(Ref. #)
ARSENIC						
algae			the various forms and compounds of As have a BAF of 4-130 (1,2,3)		algae seem to be a source of arseno-organic compounds found in higher marine organisms	
Daphnia	4.3 - 7.5 ppm	(53)				
Gambusia affinis						
crayfish						
Carp	96 hr 160 ppm	(79)				
Minnow	72 hr 27 ppm	(77)				(4)
Green sunfish	MST = 46 hrs @ 100 ppm	(95)			BAF ~550	(95)
	48 hr = 150 ppm	(97)	1			
snail			BAF = 9.20 at 0.1 ppm	(3)		
Rainbow trout	15-19 ppm mortality	(101) (102)				
Bay scallop	96 hr = 3.49 ppm	(181)				

Organism	LC_{50}	(Ref. #)	TOXICITY DATA Sublethal	(Ref. #)	Other	(Ref. #)
CADMIUM						
oyster			BAF = 0.46	(12)	no direct relationship between uptake and level of exposure	(99)
snail			BAF = 143			
lobster			BAF = 2	(12)		
Daphnia	0.05 - 3.8 ppm @ 48 hr size related	(110)				
Mummichog			BAF = 36	(12)	no relation between muscle burden and weight or length	(119)
Scallops (Bay)	96 hr 1.5 ppm	(181)				
Mussels			BAF = 400	(126)		
Killifish	96 hr = 0.11 ppm	(153)	Cd tended to accumulate more rapidly in the soft organs (liver, kidney)	(201) (167, 193)	Also check (98, 123, 124, 133, 137) 163, 164, 165, 166, 193, 200, 222, 201	
Green sunfish	96 hr = 1.5 ppm	(153)				
White perch	96 hr = 8.4 ppm	(153)				
Am. eels	96 hr = 0.82 ppm	(153)				
Carp	96 hr = 0.24 ppm	(153)				
Bass	96 hr = 1.1 ppm	(153)				
Flagfish	96 hr = 2.5 ppm	(193)				

Organism	LC_{50}	(Ref. #)	TOXICITY DATA Sublethal	(Ref. #)	Other	(Ref. #)
CESIUM						
Cyclops	48 hr = 400 ppm	(110)	No correlation between weight and body burden	(98)		
Daphnia	48 hr = 7.4 ppm	(110)				
Eudiaptomus padanus	48 hr = 135 ppm	(110)				

			TOXICITY DATA			
Organism	LC_{50}	(Ref. #)	Sublethal	(Ref. #)	Other	(Ref. #)
COBALT						
Daphnia	48 hr = 1.32 ppm	(110)	Observed growth inhibition in Cyprinus carpio at $\geq$ 5 ppm	(207)		
bacteria	48 hr = 2.5 ppm	(108)				
Cyclops	48 hr = 15.5 ppm	(110)				
Scenedesmas	48 hr = 1.0 ppm	(108)				

Organism	TOXICITY DATA LC_{50}	(Ref. #)	Sublethal	(Ref. #)	Other	(Ref. #)
COPPER						
Bluegill	96 hr = 740-1100 µg/l	(13, 14 91)	BAF 740-2900	(13, 14)	Also see 23, 15, 170, 66, 59, 171, 31, 55, 60, 80, 201, 62, 64, 65, 58, 39, 71, 72, 130, 94, 115, 169, 129, 172, 132, 222	
Ephemerella grandis	14 days = 0.18-0.20 ppm	(76)	BAF 95-9100			
Pteronarcys californica	14 days = 10-13 ppm	(76)				
Rainbow trout	24 hrs = 0.14 ppm	(56)	lethality in hard H_2O related to total concentration of Cu species	(56)		
Fathead minnow	96 hr = 0.18 ppm	(88) (110)	6 ppb = safe level for reproduction and growth in soft H_2O. 15-33 ppb = in hard (62, 63) H_2O.	(61)		
Brook Trout	96 hr = 100 ppb	(65)	copper seriously affects reproduction and growth of most species. The actual concentration at which the affect is noticeable varies from species to species			
Stickleback	6.5 days = 1 ppm	(40)				
Gambusia affinis	96 hr = 75 ppm	(81)				
Daphnia	24 hr = 1 ppm	(84)				
Gammarus	96 hr = 1.5 ppm	(90)				
Crayfish	96 hr = 0.25-3 ppm	(92)				
Killifish	96 hr = 0.86 ppm	(152)				
Green sunfish	96 hr = 2.4 ppm	(152)				
White perch	96 hr = 6.2 ppm	(152)				
Carp	96 hr = 0.81 ppm	(152)				
Am. eel	96 hr = 6.0 ppm	(153)				
parr	96 hr = 74 ppb	(187)				
smolts	96 hr = 60 ppb	(187)				

Organism	LC_{50}	(Ref. #)	TOXICITY DATA Sublethal	(Ref. #)	Other	(Ref. #)
CYANIDE						
Algae			50% reduction in growth 0.092-0.49 ppm			
Fathead minnow	96 hr = 0.17-10 ppm	(48)	for acrylonitrile affects on several species see	(52)		
Bluegill	96 hr = 0.019-390 ppm	(93)				
Brown trout	ILC 30 hr = .09 ppm	(50)	For NaCN values see	(49)		
Smallmouth bass	ILC 24 hr = 0.104 ppm	(50)				

Organism	LC_{50}	(Ref. #)	TOXICITY DATA Sublethal	(Ref. #)	Other	(Ref. #)
IRON						
			Levels in Arctic cod were higher in livers than fillets	(201)		
			Growth of Coho Salmon reduced in H_2O with 1.2 ppm Fe 10.5 ppm did not affect hatch-ability & survival	(197, 198)		

Organism	LC_{50}	(Ref. #)	TOXICITY DATA Sublethal	(Ref. #)	Other	(Ref. #)
LEAD						
Fathead minnows	96 hr = 5.6-482 ppm	(37)	Sublethal affects (31, 35, 36, 42, 43, 44, 45, 136, 76, 84, 119, 194, 196, 222) most affects are in impaired growth and spinal curvature. Some brain damage observed at 5.30 ppb S. fontinalis showed a decrease in wt. and an increase in alkaline phosphatase acetycholinesterase activity	(69)		
Bluegill	96 hr=24-442 ppm	(37)				
Goldfish	96 hr = 31.5 ppm	(37)				
Daphnia	64 hr = 1.25 ppm	(38)				
Rainbow trout	96 hr = 1 ppm	(41, 136)				
Pteronarcys californica	14 days 19.2 ppm	(80)				
Cyclops	48 hr = 5.5 ppm	(110)				
Daphnia	48 hr - 0.60 ppm	(110)				

Organism	LC_{50}	(Ref. #)	TOXICITY DATA Sublethal	(Ref. #)	Other	(Ref. #)
MERCURY						
Rainbow trout	96 hr = 0.22-0.40 as T 20°- 5°C	(9, 17)	Acute toxic action exerted on gills (BAF = 3.8-12.0)	(17)		(9)
Cyclops	48 hr = 2.2 ppm	(110)	By esophagae ligation it was shown that Hg and CH_3Hg enters fish via gills. Also CH_3Hg enters at a more rapid rate and that Hg does not require methylation prior to entry			
Daphnia	48 hr = 0.0055 ppm	(110)				
Mummichog	96 hr = 1.5 ppm	(128)				
Killifish	96 hr = 0.11	(153)				
Perch	96 hr = 0.09 ppm	(153)				
Sunfish	96 hr = 0.30 ppm	(153)				
W. Bass	96 hr = 0.22 ppm	(153)				
Carp	96 hr = 0.18 ppm	(153)				

Organism	LC_{50}	(Ref. #)	TOXICITY DATA Sublethal	(Ref. #)	Other	(Ref. #)
MOLYBDENUM						
Fathead Minnow	96 hr = 70-560 ppm depending on salt used	(106, 107)	No age and body burden correlation	(109)		
Scenedesmus			Threshold concentration for deleterious effects = 54 ppm	(108)		

Organism	LC_{50}	(Ref. #)	TOXICITY DATA Sublethal	(Ref. #)	Other	(Ref. #)
NICKEL						
Cyclops	48hr=15 ppm	(110)	Reproductive impairment (115, 45, 150, 151, 155)			
Eudiaptomus padanus	48hr=3-6 ppm	(110)			Also see	(108, 144, 149 145, 143)
Daphnia	48 hr = 1.9 ppm	(110)	Synergistic additive	(48) (148)		
Fathead minnow	96 hr = 4.6-43 depending on H_2O hardness	(117)				
Stickleback	1 week = 1ppm - survival	(113)	Lethal level = 0.8 ppm	(148)		
Goldfish) Bluegill) Guppies)	48 hr = 495 ppm	(146)	10 ppm/200 hr = no mortality	(139)		
			MLC = 48 ppm	(142)		
Channel Catfish	48 hr = 165 ppm	(146)				
Rainbow Trout	48 hr = 160 ppm	(146)				
Brown Trout	48 hr = 270 ppm	(146)				
Brook Trout	48 hr = 242 ppm	(146)				
Lake Trout	48 hr = 75 ppm	(146)				
Penaeus duorarnm	48 hr = 200 ppm	(147)				
Penaeus aztecus	48 hr = 150 ppm	(147)				
Hemigrapsis oregonensis	48 hr = 300 ppm	(147)				
Clinocardium nuttali	48 hr = 500 ppm	(147)				

Organism	LC_{50}	(Ref. #)	TOXICITY DATA Sublethal	(Ref. #)	Other	(Ref. #)
NICKEL (continued)						
Brown Shrimp	48 hr = 255 ppm	(149)				
Striped Bass	96 hr = 6.2 ppm	(152)	)			
Killifish	96 hr = 46.2 ppm	(152)	)			
Pumpkinseed	96 hr = 8.1 ppm	(152)	) Also check 153, 115,			
W. Perch	96 hr = 13.6 ppm	(152)	) 155, 108, 141.)			
Am. eel	96 hr = 13.0 ppm	(152)	)			
Carp	96 hr = 10.6 ppm	(152)	)			

Organism	TOXICITY DATA LC_{50}	(Ref. #)	Sublethal	(Ref. #)	Other	(Ref. #)
SELENIUM						
Daphnia	2.5 ppm	(108)	Uptake associated with Hg and other heavy metals (188, 189, 190, 191, 225)			
Carassius auratus	7 day = 12 ppm	(223, 224)				

Organism	TOXICITY DATA LC_{50}	(Ref. #)	Sublethal	(Ref. #)	Other	(Ref. #)
SILVER						
Pteronarcys californica	14 day = 9 ppb	(76)				
Ephemerella grandis	14 day <1 ppb	(76)				
Bay Scallops	96 hr = 33 ppb	(181)				
Rainbow Trout			If eggs exposed at 2.5 ppm, total mortality of fry due to poor larval development. (218, 219). At 1.2 ppm 40% mortality at 0.6 ppm reduced growth (219, 220)			
Fundulus heteroclitus	96 hr = 40 ppb	(215)				
Daphnia	96 hr = 30 ppb	(108)				
Scenedesmus	96 hr = 50 ppb	(108)				
Escherichia coli	96 hr = 40 ppb	(108)				

Organism	LC_{50}	(Ref. #)	TOXICITY DATA Sublethal	(Ref. #)	Other	(Ref. #)
STRONTIUM						
Cyclops	48 hr = 300 ppm	(110)				
Eudiaptomus padanus	48 hr = 180 ppm	(110)				
Daphnia	48 hr = 75 ppm	(110)				

Organism	TOXICITY DATA LC_{50}	(Ref. #)	Sublethal	(Ref. #)	Other	(Ref. #)
THALLIUM						
			In both fish and invertebrates it acts as a neuro-poison	(125, 127)		

Organism	LC_{50}	(Ref. #)	TOXICITY DATA Sublethal	(Ref. #)	Other	(Ref. #)
ZINC						
			Avoidance reaction in soft water. Rate of uptake related to temperature	(26) (24) (25, 68)		
Rainbow Trout	14 day = 0.41 ppm	(28)	For accumulation and growth see 99, 195, 27, 31, 32, 33, 2001, 29, 34, 30, 46, 45, 67, 74, 199, 193, 208			
Brown Trout	14 day = 0.64 ppm	(28)				
Cutthroat Trout	14 day = 0.67 ppm	(28)				
Brook Trout	14 day = 0.96 ppm	(28)				
Pteronarcys californica	14 day >13.9 ppm	(76)				
Fathead minnow	12 day = 1.69 ppm	(85)				
Guppy	32 hr = 1 ppm	(87)				
Gobio gobio	7 day = 8.4 ppm	(86)				
Clyclops	48 hr = 5.5 ppm	(110)				
Daphnia	48 hr = 0.040 ppm	(110)				
Killifish	96 hr = 19.1 ppm	(152)				
Carp	96 hr = 7.8 ppm	(152)				
Green sunfish	96 hr = 20 ppm	(152)				
Am. eel	96 hr = 14.6 ppm	(152)				
W. perch	96 hr = 14.3 ppm	(152)				

REFERENCES

1. WOOLSON, E.A., P.C. KEARNEY, A.R. ISENSEE, W.G. McSHANE, K.J. IRGOLIC and K.A. ZINGARO. 1974. 168th A.C.S. Meeting, Paper No. 8. Pest. Chem. Div.
2. SCHUTH, C.K., A.R. ISENSEE, E.A. WOOLSON, P.C. KEARNEY. 1974. J. Ag. Food Chem. In press.
3. ISENSEE, A.R., P.C. KEARNEY, E.A. WOOLSON, G.E. JONES and V.P. WILLIAMS. 1973. Sci. and Tech. 7(9):841-5.
4. LUNDE, G.J. 1973. J. Sci. Fd. Agric., 24:1021-27.
5. McBRIDE, B.C., and R.S. WOLFE. (1971). Biochemistry. 10,4312.
6. COX, D.P. 1974. Microbial Methylation of Arsenic, Sympos. on the Review of Arsenical Pesticides, 168th Nat'l. Meeting, American Chemical Society, Atlantic, N.J. September.
7. BRAMAN, R.S. 1974. Arsenic in the Environment. In Arsenical Pesticides ed. by E.A. Woolson in the ACS Symposium Series.
8. GILLESPIE, D.C. 1971. Mobilization of mercury from sediments into guppies (Poecilia reticulata). J. Fish. Res. Bd. Can. 29(7):1035-1041.
9. MACLEOD, J.C. and E. Pessah. 1973. Temperature effects on mercury accumulation, toxicity and metabolic rate in rainbow trout (Salmo gairdneri). J. Fish. Res. Bd. Can. 30(4):485-492.
10. OLSON, K.R., H.L. BERGMAN and P.O. FROMM. 1973. Uptake of methyl mercuric chloride and mercuric chloride by trout : A study of uptake pathways into the whole animal and uptake by erythrocytes in vitro. J. Fish. Res. Bd. Can. 30(9):1293-1239.
11. KNOLL, J. 1962. Sodium and chromate ion movement across isolated frog and fish skins with the effect of magnetic fields upon such movement. Ph.D Thesis, Michigan State University, East Lansing, Mich. 144p.
12. EISLER, R.G., G.E. ZAROOGIAN and R.J. HENNEKEY. 1972. Cadmium uptake by marine organisms. J. Fish. Bd. Can. 29(9):1367-1369.
13. BENOIT, D.A. 1975. Chronic effects of copper on survival, growth and reproduction of the bluegill(Lepomis macrochirus). Trans Am. Fish. Soc., 104(2): 353-358.
14. TRAMA, F.B. 1954. The acute toxicity of copper to the common bluegill, Lepomis macrochirus. Notulae, Natur., 257:1-13.
15. SPRAGUE, J.B., P.F. ELSON and R.L. SAUNDERS. 1965. Sublethal copper-zinc pollution in a salmon river - a field and laboratory study. Int. J. Air Water Poll., 9:531-543.

16. UTHE, J.F., F.M. ATTON, and L.M. ROYER. 1973. Uptake of mercury by caged rainbow trout (Salmo gairdneri) in the South Saskatchewan River. J. Fish. Res. Bd. Can. 30(5):643-650.

17. WOBESER, G. 1975. Acute toxicity of methyl mercury chloride and mercuric chloride for rainbow trout (Salmo gairdneri) fry and fingerlings. J. Fish Res. Bd. Can. 32(11):2005-2013

18. GARDNER, G.R., and P.P. YEVICH. 1970. Histological and hematological responses of an estuarine teleost to cadmium. J. Fish. Res. Bd. Can. 27:2185-2196.

19. BOETIUS, J. 1969. Lethal action of mercuric chloride and phenyl-mercuric acetate on fishes. Medd. Fra Dan. Fish. -og Havunders. 3:93-115.

20. AKIYAMA, A. 1970. Acute toxicity of two organic mercury compounds to the teleost, Oryzias latipes, in different stages of development. Bul. Jap. Soc. Sci. Fish. 36:563-570.

21. WOBESER, G. 1975. Prolonged oral administration of methyl mercury chloride to rainbow trout (Salmo gairdneri) fingerlings. J. Fish. Res. Bd. Can. 32(11):2015-2023.

22. RUCKER, R.R. and D.F. AMEND. 1969. Absorption and retention of organic mercurials by rainbow trout and chinook and sockeye salmon. Prog. Fish-Cult. 31:197-201.

23. GIBBS, R.N. et al. 1974. Heavy metal concentrations in museum fish specimens: effects of preservatives and time. Science, 184:475.

24. WEATHERLEY, A.H. and P. DAWSON. 1973. Zinc pollution in a freshwater system: analysis and proposed solutions. Search, Sci. Technol. Soc. 4:471.

25. JENG, S.S. and H.W. LO. 1974. High zinc concentration in common carp viscera. Bull. Jap. Soc. Sci. Fish. 40 : 509.

26. E.I.F.A.C. 1973. Water Quality Criteria for European Freshwater Fish - Report on Zinc and Freshwater Fish. F.A.O. Tech. Paper 21, Rome. Water Res. 8 :683 (1974).

27. O'REAR, C.W., JR. 1972. The toxicity of zinc and copper to striped bass eggs and fry with methods for providing confidence limits. Proc. 26th Ann. Conf. S.E. Assn. Game and Fish Comm., Oct. 22-25, 484.

28. NEHRING, R.B. and J.P. GOETTL. 1974. Acute toxicity of a zinc-polluted stream to four species of salmonids. Bull. Environ. Contam. Toxicol. 12 :464.

29. SOLBE, J.F. de L.G. 1974. The toxicity of zinc sulphate to rainbow trout in very hard water. Water Res. 8 : 389.

30. ROALES, R.R. and A. PERLMUTTER. 1974. Toxicity of zinc and cygon, applied singly and jointly by zebra fish embryos. Bull Environ. Contam. Toxicol. 12:475.

31. GOETTL, J.P. et al. 1972. Water Pollution Studies. Colorado Fisheries Res. Rev. No.1, 36, Div. Game, Fish and Parks, Fort Collins.

32. SINLEY, J.R., J.P. GOETTLE, JR., and P.H. DAVIES. 1974. Effects of zinc on rainbow trout (Salmo gairdneri) in hard and soft water. Bull. Environ. Contam. Toxicol., 12 :193.

33. BENGTSSON, B.E. 1974. Vertebral damage to minnows (Phoxinus phoxinus) exposed to zinc. Oikos. 25:134-139.

34. BENGTSSON, B.E. 1974. Effect of zinc on the movement pattern of the minnow (Phoxinus phoxinus L.). Water Research. 8:829-833

35. Adams, E.E. 1974. Uptake by brook trout of lead and hydrocarbons from snowmobile exhausts:I. Field Study II Lead and hydrocarbon content of snow after snowmobiling. III. Laboratory studies. IV. Stamina tests. Dissertation Abs., 35:74-21, 088.

36. HODSON, P.V. 1976. S-Amino levulinec acid dehydratase activity of fish blood as an indicator of a harmful exposure to lead. Jour. Fish Res. Bd. Can. 33(2):268-271.

37. PICKERING, Q.H. and C. HENDERSON. 1965. The acute toxicity of some heavy metals to different species of warm water fishes. In: Proc. 19th Ind. Waste Conf. Purdue Univ. 49(2):578-591.

38. ANDERSON, B.G. 1948. The apparent thresholds of toxicity to Daphnia magna for chlorides of various metals when added to Lake Erie water. Trans. Amer. Fish Soc. 78:96-113.

39. TARZWELL, C.M. and C. HENDERSON. 1960. Toxicity of less common metals to fishes. Ind. Wastes. 5:12.

40. JONES, J.R.E. 1938. The relative toxicity of salts and lead, zinc and copper to the stickleback (Gasterosteus aculeatas) and the effect of calcium on the toxicity of lead and zinc salts. J. Exp. Biol. 15:394-403.

41. BROWN, V.M. 1968. The calculation of the acute toxicity of mixtures of poisons to rainbow trout. Water Res. 2(10):723-733.

42. EVERHART, W.H. 1971. Unpublished data. Zoology Dept., Colorado State University, Fort Collins, Colorado.

43. CRANDALL, C.A. and C.J. GOODNIGHT. 1962. Effects of sublethal concentrations of several toxicants on growth of the common guppy (Lebistes reticulatus). Limnol. Oceanogr. 7(2):233-239.

44. JONES, J.R.E. 1939. The relation between the electrolytic solution pressures of the metals and their toxicity to the stickleback (Gasterosteus aculeatus L.) J. Exp. Biol., 16:425-437.

45. BIESENGER, K.E. and G.M. CHRISTENSEN. 1971. Unpublished data. Metal effects on survival, growth, reproduction and metabolism of Daphnia magna.

46. BRUNGS, W.A. 1969. Chronic toxicity of zinc to the fathead minnow, Pimephales promelas R. Trans. Am. Fish. Soc. 98(2):272-279.

47. CHEREMISENOFF, P.N. and Y.H. HABIB. 1973. Cyanide - an assessment of alternatives for water pollution control. Water and Sewage Works, 120, R95.

48. DOUDOROFF, P. 1956. Some experiments on the toxicity of complex cyanides to fish. Sewage and Industrial Wastes, 28(8):1020-1040.

49. DOUDOROFF, P., G. LEDUC and C.R. SCHNEIDER. 1966. Acute toxicity to fish of solutions containing complex metal cyanides, in relation to concentrations of molecular hydrocyanic acid. Trans. Am. Fish. Soc. 95(1):6-22.

50. BURDICK, G.E., H.J. DEAN and E.J. HARRIS. 1958. Toxicity of cyanide to brown trout and smallmouth bass. N.Y. Fish Game. J. 5(2):133-163.

51. BURDICK, G.E. and M. LIPSCHUETZ. 1948. Toxicity of ferro- and ferrocyanide solutions to fish and determination of the cause of mortality. Trans Am. Fish Soc. 78:192-202.

52. HENDERSON, C., Q.H. PICKERING and A.E. LEMKE. 1960. The effect of some organic cyanides (nitriles) on fish. Purdue Univ. Eng. Bull. Ext. Ser. No. 106:120-130.

53. ANDERSON, B.G. 1946. The toxicity thresholds of various sodium salts determined by the use of Daphnia magna. Sewage Works J. 18:82-87.

54. PENROSE, W.R. 1975. Biosynthesis of organic arsenic compounds in brown trout (Salmo trutta). J. Fish. Res. Bd. Can. 32(12):2385-2390.

55. McKIM, J.M. and D.A. BENOIT. 1974. Duration of toxicity tests for establishing no effect concentrations for copper with brook trout (Salvelinus fontinalis). J. Fish. Res, Bd. Can. 31(4):449-452.

56. SHAW, T.L. and V.M. BROWN. 1974. The toxicity of some forms of copper to rainbow trout. Water Research. 8:377-382.

57. BROWN, V.M., T.L. SHAW and D.G. SHURBER. 1974. Aspects of water quality and the toxicity of copper to rainbow trout. Water Research 8:797-803.

58. REIMER, D.N. and S.J. TOTH. 1970. Adsorption of copper by clay minerals, humic acid and bottom muds. J. Am. Wat. Wks. Assoc. 62(3):195-197.

59. PAGENKOPF, G.K., R.C. RUSSO and R.V. THURSTON. 1974. Effect of complexation on toxicity of copper to fishes. J. Fish. Res. Bd. Can. 31(4):462-465.

60. WESTLAKE, G.F. and H. KLEEREKOPER. 1974. The locomotor response of goldfish to a steep gradient of copper ions. Water Resources Res. 10 : 103.

61. BIESENGER, K.E., G. GLASS and R.W. ANDREW. 1971. Unpublished data. Toxicity of copper to Daphnia magna. National Water Quality Laboratory, Duluth, Minn.

62. MOUNT, D.I. 1966. Chronic toxicity of copper to fathead minnows (Pimephales promelas R). Water Res. 2(3):215-223.

63. MOUNT. D.I. and C.E. STEPHAN. 1969. Chronic toxicity of copper to the fathead minnow (Pimephales promelas) in soft water. J. Fish. Res. Bd. Can. 26(9):2449-2457.

64. BRUNGS, W.A. 1971. Unpublished data. National Water Quality Laboratory, Duluth, Minn.

65. McKIM, J.M. and D.A. BENOIT. 1971. Effects of long term exposures to copper on survival, growth and reproduction of brook trout (Salvelinus fontinalis). Fish. Res. Bd. Can. 28(5):655-662.

66. Lloyd, R. 1961. The toxicity of zinc and copper sulphates to rainbow trout (Salmo gairdneri R.). Ann. Appl. Biol. 49: 535-538.

67. Lloyd, R. 1960. The toxicity of zinc sulphate to rainbow trout. Ann. Appl. Biol., 48(1):84-94.

68. HODSON, P.V. 1975. Zinc uptake by Atlantic salmon (Salmo salar) exposed to a lethal concentration of zinc at 3, 11 and 19^{o}C. J. Fish. Res. Bd. Can. 32(12):2552-2556.

69. CHRISTENSEN, G.M. 1975. Biochemical effects of methylmercuric chloride, cadmium chloride and lead nitrate on embryos and alevins of the brook trout, (Salvelinus fontinalis). Tox. Appl. Pharm. 32:191-197.

70. OLSON, G.F., D.I. MOUNT., V.M. SNARSKI and T.W. THORSLUND. 1975. Mercury residues in fathead minnows, (Pimephales promelas R.) chronically exposed to methylmerucy in water. Bull. Environ. Contam. Toxicol. 14(2):129-134.

71. HAZEL, C.R. and S.J. MEITH. 1970. Bioassay of king salmon eggs and sac fry in copper solutions. Calif. Fish and Game. 56(2):121-124.

72. McKIM, J.M., G.M. CHRISTENSEN and E.P. Hunt. 1970. Changes in the blood of brook trout (Salvelinus fontinalis) after short-term and long-term exposure to copper. J. Fish. Res. Bd. of Can. 27(10): 1883-1889.

73. BANDT, H.J. 1946. Ueber verstarkte Schadwirkungen auf fische islesondere uber erhonte Gifeuirkung durch Kombination von abwassergiften. Beitr. Wasserchem, 1:15-23.

74. CRANDALL, C.A. and C.J. GOODNIGHT. 1963. The effects of sublethal concentrations of several toxicants to the common guppy, Lebistes reticulatus. Trans. Am. Microscop. Soc., 82:59-73.

75. SKIDMORE, J. 1964. Toxicity of zinc compounds to aquatic animals with special reference to fish. Quart. Rev. of Biol., 39(3): 227-248.

76. NEHRING, R.B. 1976. Aquatic insects as biological monitors of heavy metal pollution. Bull. Environ. Contam. Toxicol. 15(2):147-154.

77. BOSCHETTI, M.M. and T.E. McLOUGHLIN. 1957. Toxicity of sodium arsenite to minnows. Tanitalk 5(4):14-18.

78. HOLLAND, G.A., J.E. LASATER, E.D. NEUMAN and W.E. ELDRIDGE. 1960. Toxic effects of organic and inorganic pollutants on young salmon and trout. Wash. Dept. Fish. Res. Bull. No.5. 264p.

79. MALACEA, I. 1966. Contributions to knowledge on the toxic effect of cyanides, ammonia, mercury, and florsenic on some species of fish and on Daphnia. Stud. Prot. Epurarea Apelor Inst. Itud. Cerect. Hidrotek. 7:751-792.

80. TURNBULL, H., J.G. DeMANN and R.F. WESTON. 1954. Toxicity of various refinery materials to fresh water fish. Ind. Eng. Chem. 46:324-333.

81. WALLEN, I.E., W.C. GREER and R. LASATER. 1957. Toxicity to Gambusia affinis of certain pure chemicals in turbid waters. Sewage Indust. Wastes. 29:695-711.

82. GILL, J.M., J.H. HAQUET and E.A. PEARSON. 1960. Submarine dispersal system for treated chemical wastes. J. Water Pollut. Contr. Fed. 32:858-867.

83. DORFMAN, D. and W.R. Whitworth. 1969. Effects of fluctuations of lead, temperature and dissolved oxygen on the growth of brook trout. J. Fish. Res. Bd. Can. 26(9):2493-2501.

84. KARUJA, T.H. HAGA, G. HAGA and K. KIMURA. 1969. Post mortem identification of the pollutant in fish killed by water pollution. X. Acute poisoning with lead. Bull. Jap. Soc. Sci. Fish. 35(12):1167-1171.

85. PICKERING, Q.H. and W.N. VIGOR. 1965. The acute toxicity of zinc to eggs and fry of the fathead minnow. Prog. Fish-Cult. 27(3):153-157.

86. BALL.I.R. 1967. Toxicity of cadmium to rainbow trout (Salmo gairdneri Richardson). Water Res. 1(11/12):805-806.

87. CHEN, C.W. and R.E. SELLECK. 1968. A kinetic model of fish toxicity threshold. J. Water Pollut. Cont. Fed. 41 (8 part 2):R294-R308.

88. PALMER, C.M. and T.E. MALONEY. 1955. Preliminary screening for potential algicides. Ohio J. Sci. 55(1):1-8.

89. FLOCH, H., R. DESCHIENS, and Y. Le CORROLLER. 1963. The molluscidal properties of Chevreal's coprosulphite salt in the prophylaxis of schistozomiasis. Bull. Soc. Pathol. Exot. 56(2):182-189.

90. NEBEKER, A.V. and A.R. GAUFIN. 1964. Bioassay to determine pesticide toxicity to the amphipod crustacean (Gammarus lacustris) Proc. Utah. Acad Sci. Arts. Lett. 41(1):64-67.

91. COPE, O.B. 1965. Sport Fishery investigation, in "Effects of pesticides on fish and wildlife: 1964 research findings of the Fish and Wildlife Service. U.S. Fish and Wildlife Circular No. 226. Government Printing Office, Washington D.C. pp.51-53.

92. HUBSCHMAN, J.H. 1967. Effects of copper on the crayfish Orconectes rusticus (Girard). I Acute Toxicity. Crusteana. 12(11):33-42.

93. CARINS, J,Jr. and A. SCHEIER. 1968. The comparison of the toxicity of some common industrial waste components tested individually and combined. Prog. Fish Cult. 30(1):3-8.

94. BRUNGS, W.A., J.R. GECKLER and M. GAST. 1976. Acute and chronic toxicity of copper to the fathead minnow in a surface water of variable quality. Water Research, 10:37-43.

95. SORENSEN, E.M.B. 1976. Toxicity and accumulation of arsenic in green sunfish Lepomis cyanellus, exposed to arsenate in water. Bull. Environ. Contam. Toxicol. 15(6):256-261.

96. MASON, J.W., J.H. CHO and A.C. ANDERSON. 1976. Uptake and loss of inorganic mercury in the eastern oyster (Crassostrea virginica)

97. SORENSEN, E.M.B. 1974. Ph.D. Thesis. The University of Texas at Austin.

98. KEVERN, N.R. 1966. Feeding rate of carp estimated by a radioisotopic method. Trans. Am. Fish. Soc. 95(2):363-371.

99. LOVETT, R.J., W.J. GUTENMANN, I.S. PAKKALA, W.D. YOUNG, D.J. LISK, G.E. BURDICK and E.J. HARRIS. 1972. A Survey of the total cadmium content of 406 fish from 49 New York State fresh waters. J. Fish. Res. Bd. Can. 29(9):1283-1290.

98. MOUNT. D.I. and C.E. STEPHAN. 1967. A method for detecting cadmium poisoning in fish. J. Wildl. Management. 31(1):168-172.

99. MOUNT, D.I. 1964. An autopsy technique for zinc-caused fish mortality. Trans. Am. Fish. Soc. 93(2):174-182.

100. LAARMAN, P.W., W.A. WILFORD and J.R. OLSON. 1976. Retention of mercury in the muscle of yellow perch (Perca flavescens) and rock bass (Ambloplites rupestris). Trans. Am. Fish Soc. 105(2):296-300.

101. DABROWSKI, K.R. 1976. The effect of arsenic on embrional development of rainbow trout (Salmo gairdneri, Rich.). Water Research. 10: 793-796.

102. LIEBMANN, H. 1960. Handbuch der Frisch-wasser und Abevasser. Biologie. 2:792-795.

103. KLASS, E., D.W. ROWE and E.J. MASSARO. 1974. The effect of cadmium on population growth of the green alga. Scenedesmus quadracauda. Bull. Environ. Contam. Tox. 12(4):442-445.

104. DORN, P. 1976. The feeding behaviour of Mytilus edulis in the presence of methylmercury acetate. Bull. Environ. Contam. Toxicol. 15(6): 714-719.

105. NAMMINGA, H.E., J.E. SCOTT and S.L. BURKS. 1974. Distribution of copper, lead and zinc in selected components of a pond ecosystem. Proc. Okla. Acad. Sci. 54:62-64.

106. PEK, S.L., K.L. BAINBRIDGE and M. WILKINSON. 1975. Investigations of the biological action of materials associated with ore mining and milling to aquatic organisms. A. Molybdenium B. Antimony C. Arosurf MG98A (Flotation Reagent). Calspan Report No. 196, 28pp.

107. TARZWELL, C.M. and C. HENDERSON. 1956. Toxicity of less common metals to fishes. Trans Sem. on Sanitary Engineering Aspects of the Atomic Energy Industry. Robt. H. Taft. Sanitary Eng. Centre. TID-7517.

108. BRINGMANN, G. and R. KUHA. 1959. The toxic effects of wastewater on aquatic bacteria, algae, and small crustaceans. Gesundheits-Ing. 80:115.

109. TONG, S.S.C., W.D. YOUNGS, W.H. GUTENMANN and D.J. LISK. 1974. Trace metals in Lake Cayuga lake trout (Salvelinus namaycush) in relation to age. J. Fish. Res. Bd. Can. 31(2):238-239.

110. BAUDOUIN, M.F. and P. SCOPPA. 1974. Acute toxicity of various metals to freshwater zooplankton. Bull. Environ. Contam. Toxicol. 12(6): 745-751.

111. PULLEY, T.E. 1950. Effect of AlCl in small concentrations on various marine organisms. Texal. Journ. of Sci. 2:405-411.

112. EVERHART, W.H. and R.A. FREEMAN. 1973. Effects of chemical variations in aquatic environments. Vol. II Toxic Effects of Aqueous Al to rainbow trout. E.P.A. Ecological Research Series Report #EPA-R3-73-011b. Feb. 1973. 41pp.

113. DOUDOROFF, P. and M. KATZ. 1953. Critical reviews of literature on the toxicity of industrial wastes and their components to fish. II. The metals, as salts. Sewage & Ind. Wastes, 25 :802.

114. WARNICK, S.L. and H.L. BELL. 1969. The acute toxicity of some heavy metals to different species of aquatic insects. J. Wat. Poll. Contr. Fed. 41:280-284.

115. BIESINGER, K.W. and G.M. Christensen. 1972. Effects of various metals on survival, growth, reproduction and metabolism of Daphnia magna. J. Fish. Res. Bd. Can. 29:1691-1700.

116. FREEMAN, L. and I. Fowler. 1953. Toxicity of combinations of certain inorganic compounds to Daphnia magna Strauss. Sew. Ind. Wastes. 25:1191-1195.

117. PICKERING, Q.H. and C. HENDERSON. 1966. Acute toxicity of some important petrochemicals to fish. J. Water Poll. Contr. Fed. Sept. 1419-1429.

118. TRAMA, F.B. and R.J. BENOIT. 1960. Toxicity of hexavalent chromium to bluegills. J. Wat. Poll. Contr. Fed. 32:869-877.

119. MATHIS, B.J. and N.R. KEVERN. 1975. Distribution of mercury, cadmium lead and thallium in a eutrophic lake. Hydrobiologia 46(2-3):207-222.

120. JOHNELS, A.G., T. WESTERMARK, W. BERG, P. PERSSON and B. SJOSTRAND. 1967. Pike (Esox lucius L.) and some other aquatic organisms in Sweden as indicators of mercury contamination in the environment. Oikos 18(2):323-333.

121. HANNERZ, L. 1968. Experimental investigations of the accumulation of mercury in water organisms. Fishery Board of Sweden Institute of Freshwater Research, Drottningholm Report No. 48:120-176.

122. WOBESER, G. N.O. NIELSEN, R.H. DUNLOP and F.M. ATTON. 1970. Mercury concentrations in tissues of fish from the Saskatchewan River. J. Fish Res. Bd. Can. 27(4):830-834.

123. GOULD, E., R.S. COLLIER, J.J. KAROLUS and S. GIVENS. 1976. Heart transaminase in the rock crab, Cancer irroratus exposed to cadmium salts. Bull. Environ. Contam. Toxicol. 15(6):635-643.

124. GILLES, R. 1973. Netherlands J. Sea. Res. 7 :280.

125. ZITKO, V. and W.V. CARSON. 1975. Accumulation of thallium in clams and mussels. Bull. Environ. Contam. Toxicol. 14(5):530-533.

126. MAJORI, L. and T. PETRONIO. 1973. Hgiene Moderna, 66:19. Fisheries and Marine Service Translation Series No. 3118.

127. WILBER, C.G. 1969. The Biological Aspects of Water Pollution (C.C. Thomas Publisher, Springfield Illinois)296P.

128, KLAUNIS, J, S. KOEPP and M.McCORMICK. 1975. Acute toxicity of a native mummichog population (Fundulus heteroclitus) to mercury. Bull. Environ. Contam. Toxicol. 14(5):534-536.

129. WINNER, R.W., J.S. VAN DYKE, N. CARIS and M.P. FARREL. 1975. Response of the Macroinvertebrate fauna to a copper gradient in an experimentally-polluted stream. Verh. Internat. Verein. Limnol. 19:2121-2127.

130. WINNER, R.W. and M.P. FARRELL. 1976. Acute and chronic toxicity of copper to four species of Daphnia. J. Fish. Res. Bd. Can. 33(8):1685-1691.

131. WINNER, R.W. 1976. Toxicity of copper to daphnids in reconstituted and natural waters. Ecological Research Series report E.P.A.-600/3-76-051, May 1976.

132. BUTCHER, R.W. 1946. The biological detection of pollution. J. Institit. Sew. Purif. 2 : 92-97.

133. SANFORD, W.C. 1974. Effects of cadmium salts on the reproductive potential of male rainbow trout as determined by in vivo and in vitro techniques. Project OWRR-A-042-OKLA, Office of Water Resources Research, Washington, D.C.

134. SAYLER, G.I. and R.R. COLWELL. 1976. Partitioning of mercury and polychorinated biphenyls by oil, water and suspended sediment. Env. Sci. and Tech. 10(12):1142-1145.

135. MOUNT. D.I. 1968. Chronic toxicity of copper to fathead minnows (Pimephales promelas Rafinesque) Water Res. 2:215-223.

136. DAVIES,P.H. and W.H. Everhart. 1973. Effects of chemical variations in aquatic environments:lead toxicity to rainbow trout and testing application factor concept. U.S. Environmental Protection Agency Report Number, EPA-R3-73-011c, Washington, D.C.

137. EATON, J.G. 1974. Chronic cadmium toxicity to the bluegill (Lepomis macrochirus Rafinesque). Trans. Am. Fish. Soc. 103:729-735.

138. PICKERING, Q.H., unpublished data. 1971. Newton Fish Toxicology Laboratory, Cincinnati, Ohio.

139. ELLIS, M.M. 1937. Detection and measurement of stream pollution. U.S. Bur. Fish Bull. No. 22:365-437.

140. WOOD, C.S. 1964. New Zealand Marine Department, Technical Report No. 10, Wellington, New Zealand, 214p.

141. MURDOCH, H.R. 1953. Industrial Wastes. Ind. Eng. Chem. 45(12):99A-102A.

142. SHAW. W.H.R. and B.R. LAWRENCE. 1956. Bioassay for the estimation of metal ions. Anal. Chem. 28:1164-1166.

143. RUDOLFS, W. et al. 1953. Industrial Wastes. Reinhold Publishing Co., New York, New York.

144. HAYDU, E.P. unpublished data. Water Resources and Management, Weyerhaeuser Company, Pulp and Paper Board Division, Longview Washington.

145. CALABRESSE, A., R.S. COLLIER, D.A. NELSON and J.R. MACINNES. Unpublished data. The toxicity of heavy metals to embryos of the American oyster (Crassostrea virginica). National Marine Fisheries Service Laboratory for Experimental Biology, Milford, Conn.

146. WILLFORD, W.A. 1966. Toxicity of twenty-two therapeutic compounds to six fishes, in Investigations in fish control. No.20. U.S. Fish and Wildlife Service Bureau Sport Fish Wildlife, Resource Publication. 35, 10p.

147. PORTMANN, J.E. 1968. Progress report on the program of insecticide analysis and toxicity testing in relation to the marine environment. Meersuntersuchungen. 17(1-4):247-256.

148. BROWN, V.M. and R.A. WALTON. 1970. The acute lethal toxicity to rainbow trout of mixtures of copper, phenol, zinc and nickel. J. Fish. Biol. 2 :211-216.

149. PORTMANN, J.E. and K.W. WILSON. 1971. The toxicity of 140 substances to the brown shrimp and other marine animals. Ministry of Agriculture, Fisheries and Food, Fisheries Laboratory, Burnham-on-Crouch, Essex, England. Shellfish Information Leaflet No.22. 12pp. AMIC-7704.

150. SHAW. T.L. and V.M. BROWN. 1971. Heavy metals and the fertilization of rainbow trout eggs. Nature, 230 (529):251. AMIC-1444.

151. OTTO, N.E. 1970. Algaecidal evaluation and environmental study of mat producing blue green algae. Bureau of Reclamation, Office of Chief Engineer, Denver, Colorado, Report No. REC-OCE-70-25. 31pp, PB-194-808.

152. REHWOLDT, R., G. BIDA and B. NERRIE. 1971. Acute Toxicity of copper nickel and zinc ions to some Hudson River Fish Species. Bull. Env. Contam. Toxicol. 6(5) :445.

153. REHWOLDT, R., L.W. MENAPACE, B. NERRIE and D. ALESSANDRELLO. 1972. The effect of increased temperature upon the acute toxicity of some heavy metal ions. Bull. Env. Contam. Toxicol. 8(2):91.

154. KIHLSTROM, J.E. and L.HULTH. 1972. The effect of phenylmercuric acetate upon the frequency of hatching of eggs from the zebra-fish. Bull. Env. Contam. Toxicol. 7(213):111.

155. PICKERING, Q.H. 1974. Chronic toxicity of nickel to the fathead minnow. J. Water. Poll. Contr. Fed. 46(4):760.

156. DRUMMOND, R.A., G.F. OLSON and A.R. BUTTERMAN. 1974. Cough response and uptake of mercury in brook trout (Salvelinus fontinalis) exposed to mercuric compounds at different hydrogen-ion concentrations. Trans. Am. Fish Soc. 105(2).

157. COLLIER, R.S., J.E. MILLER, M.A. DAWSON and F.P. THUNBERY. 1973. Physiological response of the mud crab (Eurypsanopous depressus) to cadmium. Bull. Env. Contam. Toxicol. 10(6):378.

158. JONES, J.R.E. 1957. "Fish and river pollution". Chapt. 7 of Aspects of River Pollution. L. Klein (ed.). Butterworth Scientific Publ. London.

159. HEM, J.D. and C.E. ROBERTSON. 1969. Form and Stability of aluminum hydroxide complexes in dilute solution. U.S. G.S. Water Supply Paper 1827-B.

160. De BRUIN, A. 1971. Certain biological effects of lead upon the animal organism. Arch. Environ. Health. 23(4):249-264.

161. CHISOLM, J.J. Jr., 1971. Lead poisoning. Scientific American. 224(2):15-23.

162. STUMM, W. and J.J. MORGAN. 1970. Aquatic Chemistry. An introduction emphasizing chemical equilibria in natural waters. Wiley Interscience, New York. 583p.

163. BENOIT, D.A., E.N. LEONARD, G.M. CHRISTENSEN and J.T. Fiandt. 1976. Toxic effects of cadmium on three generations of brook trout (Salvelinus fontinalis). Trans. Am. Fish Soc. 105(4):550-560.

164. SANGALUNG, G.B. and M.J. O'HALLORAN. 1972. Cadmium induced testicular injury and alterations of androgen synthesis in brook trout. Nature 240:470-471.

165. CEARLEY, J.E. and R.L. COLEMAN. 1974. Cadmium toxicity and bioconcentration in largemouth bass and bluegill. Bull Env. Contam. Toxicol. 11(2):146.

166. ROWE, D.W. and E.J. MASSARO. 1974. Cadmium uptake and time dependent alterations in tissue levels in the white catfish, (Ictalurus catus (Pisces:Ictaluridae). Bull. Env. Contam. Toxicol. 11(3): 244.

167. PISCATOR, M. 1964. Nord, Hyg. Tidsler. 45:76.

168. BLACK, G.A.P., D.J. HURTON, H.C. JOHNSTON and J.B. SPRAGUE. 1976. Annotated list of copper concentrations found harmful to aquatic organisms. FMS Tech. Rept. 603.

169. GRANDE, M. 1967. Effect of copper and sinc on salmonid fishes. 3rd Internat. Conf. Wat. Pollut. Res.

170. SPRAGUE, J.B. and B.D. RAMSEY. 1965. Lethal levels of mixed copper-zinc solution for juvenile salmon. J. Fish. Res. Bd. Can. 22(2): 425-432.

171. SPRAGUE, J.B. 1964a. Lethal concentrations of copper and zinc for young Atlantic salmon. J. Fish. Res. Bd. Can. 21(1):17-26.

172. ARTHUR, J.W. and E.N. LEONARD. 1970. Effects of copper on Gammarus pseudolimnaeus, Physa integra and Campeloma decisum in soft water. J. Fish. Res. Bd. Can. 27:1277-1283.

173. LIEPOLT, R and E. WEBER. 1958. Die Giftwirkung von Kupfersulfat auf Wasserorganismen. Wass. u. Abwasser, 1958:335-353.

174. RIVERS, J.B., J.E. PEARSON and C.D. SHULTZ. 1972. Total and organic mercury in marine fish. Bull. Environ. Contam. Toxicol. 8(5): 257-266.

175. NORSETH, T. and T.W. CLARKSON. 1970. Arch. Environ. Health 21: 717.

176. NORSETH, T and T.W. Clarkson. 1970. Biochem. Pharmacology 19 : 1775.

177. MATSUMURA, F., Y GOTOH and G.M. BOUSCH. 1972. Factors influencing translocation and transformation of mercury in river sediment. Bull. Environ. Contam. Toxicol. 8(5):267-272.

178. KONRAD, J.G. 1971. Res. Rept. Dept. of Natural Resources, State of Wisconsin.

179. KAMPS, L.R., K. CARR and H. MILLER. 1972. Total mercury-monomethyl-mercury content of several species of fish. Bull. Environ. Contam. Toxicol. 8(5): 273-279.

180. WESTOO, G., and M. RYDALV. 1971. Var. Foda 23, 179.

181. NELSON, D.A., A. CALABRESE, B.A. NELSON, J.R. MACINNES and D.R. ENZLOFF. 1976. Biological aspects of heavy metals on juvenile bay scallops (Argopecten irradians), in short tem exposures. Bull. Env. Contam. Toxicol. 16(3):275-282.

182. GILDERHERS, P.A. 1966. Some effects of sublethal concentrations of sodium arsenite on bluegills and the aquatic environment. Trans. Am. Fish Soc. 15(3):289-296.

183. UTHE, J.F. 1972. Mercury in the aquatic environment : A summary of research carried out by the Freshwater Institute 1970-1971. Fish Res. Bd. Can., Manuscript Report Series No. 1167, 163pp.

184. GILLESPIE, D.C. 1972. Uptake of mercury by guppies (Lebistes reticulatus) from mercury contaminated sediments. In 183.

185. HAMILTON, A.L 1972. Pond experiments on the uptake and elimination of mercury by selected freshwater organisms. In 183.

186. DOYLE, M., S. KOEPP and J. KLAUNIG. 1976. Acute toxicological response of the crayfish (Orconectes limosus) to mercury. Bull. Env. Contam. Toxicol. 16(4):422-424.

187. LORZ, H.W., and B.P. McPHERSON. 1976. Effects of copper or zinc in freshwater on the adaptation to sea water and A.T. Pase activity and the effects of copper on migratory disposition of coho salmon (Oncorhynchus kisutch). J. Fish. Res. Bd. Can 33(9):2023-2030.

188. FOWLER, S.W. and G. BENAYOUN. 1976. Accumulation and distribution of selenium in mussel and shrimp tissues. Bull. Env. Cont. Toxicol. 16(3):339-346.

189. McKAY, N.J. M.N. KAZACOS, R.J. WILLIAMS and M.I. LEEDOW. 1975. Mar. Pollut. Bull. 6 : 57.

190. SANDHOLM, M., H.E. OKSANEN, and L. PESONEN. 1973. Uptake of selenium by aquatic organisms. Limn. Oceanogr. 18(3):496-498.

191. KOEMAN, J.H., W.S.M. van de Ven., J.J.M. GOEY., P.S. TJIOE and J.L van HAAFTEN. 1975. Mercury and selenium in marine mammals and birds. In : The Science of the Total Environment 3, pp 279-287. Elsevier Scientific Publishing Company, Amsterdam.

192. McKIM, J.M., G.F. OLSON, G.W. HOLCOMBE and E.P. HUNT. 1976. Long term effects of methylmercuric chloride on three generations of brook trout (Salvelinus fontinalis) : Toxicity accumulation, distribution and elimination. J. Fish. Res. Bd. Can. 33(12):2726-2739.

193. SPEHAR, R.L. 1976. Cadmium and zinc toxicity to flagfish (Jordanella floridae). J. Fish. Res. Bd. Can. 33:1939-1945.

194. HOLCOMBE, G.W., D.A. BENOIT, E.N. LEONARD and J.M. McKIM. 1976. Long-term effects of lead exposure on three generations of brook trout (Salvelinus fontinalis). J. Fish. Res. Bd. Can. 33:1731-1741.

195. WEDEMEYER, G. 1968. Uptake and distribution of Zn^{65} in the coho salmon egg (Oncorhynchus kisutch). Comp. Biochem. Physiol. 26:271-279.

196. PAGENKOPF, G.K. and D.R. NAIMAN. 1974. Lead Concentrations in native trout. Bull. Environ. Contam. Toxicol. 12:70-75.

197. SMITH, E.J. and J.L. Sykora. 1976. Early developmental effects of lime-neutralized iron hydroxide suspension on brook trout and coho salmon. Trans. Am. Fish Soc. 105(2):308-312.

198. UPDEGRAFF, K.F. and J.L. SYKORA. 1976. Avoidance of lime neutralized iron hydroxide solutions by coho salmon in the laboratory. Env. Sci. Tech. 10(1):51-54.

199. WATSON, T.A. and B.A. McKEOWN. 1976. The effect of sublethal concentrations of zinc on growth and plasma glucose levels in rainbow trout (Salmo gairdneri Richardson). J. Wildl. Dis. 12:263-270.

200. WEIS, P and J.S. WEISS. 1976. Effects of heavy metals on fin regeneration in the killifish (Fundulus heteroclitus). Bull. Env. Contam. Toxicol. 16(2):197-201.

201. Bohn, A., and R.O. McELROY. 1976. Trace metals (As, Cd, Cu, Fe and Zn) in Arctic cod, (Boreogadus saida) and selected zooplankton from Strathcona Sound, Northern Baffin Island. J. Fish. Res. Bd. Can. 33:2836-2840.

202. BUHLER, D.R., R.M. STOKES and R.S. CALDWELL. 1977. Tissue accumulation and enzymatic effects of hexavalent chromium in rainbow trout (Salmo gairdneri). J. Fish Res. Bd. Can. 34(1):9-18.

203. FELDMAN, F.J. 1968. The state of chromium in biological materials Fed. Proc. 27:482.

204. MERTZ, W. 1969. Chromium occurence and function in biological systems. Physiol. Rev. 49:163-239.

205. SANDERS, H.O. and O.B. COPE. 1966. Toxicities of several pesticides to two species of cladocerans. Trans. Am. Fish. Soc. 95(2): 165-169.

206. COPE, O.B. 1966. Contamination of the freshwater ecosystem by pesticides. J. Appl. Ecol. 3(supp.):33-44. Supplement 3 published as Pesticides in The Environment and their effects on Wildlife. N.W. Moore ed. (Blackwell Scientific Publications, Oxford).

207. SHABALINA, A.A. 1964. The Effect of cobalt on the growth of young carp and filamentous green algae. I. sv. naucho-issled. Inst. Oserm. recha. ryb. Khog. 57:290-294.

208. AFFLECK, R.J. 1952. Zinc poisoning in a trout hatchery. Australian Journal of Marine and Freshwater Research. 3:142-169.

209. REHWOLDT, R., L. LASKO, C. SHAW and E. WIRKOWSKI. 1973. The acute toxicity of some heavy metal ions toward benthic organisms. Bull. Environ. Contam. Toxicol. 10:291-294.

210. OLSON, P.A. 1958. Comparative toxicity of Cr (VI) and Cr (III) in salmon. Hanford Biological Research Annual Report for 1957. HW-53500, Richland, Washington pp.215-218.

211. BENOIT, D.A. 1971. Unpublished data. Long-term effects of hexavalent chromium on the growth, survival and reproduction of the brook trout and rainbow trout. National Water Quality Laboratory, Duluth, Minn.

212. BIESINGER, K.E. and G.M. CHRISTIENSEN. 1971. Unpublished data. Metals effects on survival, growth, reproduction and metabolism of Daphnia magna. National Water Quality Laboratory, Duluth, Minn.

213. DOWDEN, B.F. and H.J. BENNETT. 1965. Toxicity of selected chemicals to certain animals. J. Water Pollut. Cont. Fed. 37(9):1308-1316.

214. PICKERING, Q.H. and C. HENDERSON. 1965. The acute toxicity of some heavy metals to different species of warm water fishes. Purdue Univ. Eng. Bull. Ext. Ser. No. 117:578-591.

215. JACKIM, E., J.M. HAMLIN and S. SONIS. 1970. Effects of metal poisoning on five liver enzymes in the killifish (Fundulus heteroclitus). J. Fish. Res. Bd. Can. 27(2):383-390.

216. JONES. J.R.E 1948. A further study of the reactions of fish to toxic solutions. Journal of Experimental Biology. 25:22-34.

217. NEHRING, R.B. 1973. Heavy metal toxicity in two species of aquatic insects. Masters Thesis, Colorado State University, Ft. Collins, Colorado.

218. AMIARD, J.C. 1976. Phototactic variations in crustacean larvae due to diverse metallic pollutants demonstrated by a sublethal toxicity test. Marine Biology 34:239-245.

219. GOETTL, J.P., J.R. SINLEY and P.H. DAVIES. 1973. Water Pollution Studies. Colorado Division of Wildlife, Job Progress Report, Federal Acid Project F-33-R-8, 123 pages.

220. GOETTL, J.P., J.R. FINLEY and P.H. DAVIES. 1974. Water Pollution Studies, Colorado Division of Wildlife, Job Progress Report, Federal Aid Project F-33-R-8, 123 pages.

221. GOETTL , J.P. and P.H. DAVIES. 1975. Water Pollution Studies, Colorado Division of Wildlife, Job Progress Report, Federal Aid Project F-33-R-10.

222. SAUTER, S., K.S. BUXTON, K.J. MACEK and S.R. PETROCELLI. 1976. Effects of exposure to heavy metals on selected freshwater fish. EPA Report EPA 600/3-76-088.

223. NIIMI, A.J. and Q.N. LAHAM. 1975. Selenium toxicity on the early life stages of zebrafish (Brachydanio rerio). J. Fish. Res. Bd. Can. 32(6):803-806.

224. WEIR, P.A. and C.H. HINE. 1970. Effects of various metals on behaviour of conditioned goldfish. Arch. Environ. Health 20:45-50.

225. HUCKABEE, J.W. and N.A. GRIFFITH. 1974. Toxicity of mercury and selenium to the eggs of carp (Cyprinus carpio). Trans. Am. Fish. Soc. 103: 822-825.